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EPA (Environmental Protection Agency) Design Information Report: Design, Operational, and Cost Considerations for Vacuum Assisted Sludge Dewatering Bed Systems

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16. ABSTRACT

The vacuum assisted sludge dewatering bed (VASDB) process is a U.S. technology developed in the mid-1970s as an alternative to the more conventional sludge drying bed process. At the present time three manufacturers are marketing VASDB systems.

Although the application of this technology has been increasing since the mid-1970s, operational system design, performance and cost information has not been amassed, analyzed and interpreted. During the course of this investigation, twelve operational VASDB systems were visited.

Data and information from these twelve sites, as well as from other sources, were analyzed with the goal of identifying design and operational considerations which might be expected to yield supplemental cost-effectiveness, flexibility and reliability to the VASDB process. Substantial variations in system design criteria and operational practices were noted, both of which had impacts on the total cost of dewatering sludges using this technology. Factors accounting for these variabilities were subsequently identified and recommendations were developed to optimize system performance and costs. A subsequent comparisons of costs between VASDB and sludge drying bed systems indicated the appropriateness of utilizing the VASDB process, especially at small to medium sized wastewater treatment facilities.

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EPA Design Information Report

The U. S. Environmental Protection Agency has undertaken a program to help municipalities and engineers avoid problems in wastewater treatment facility design. A series of documents will be produced that identify frequently occurring process design problems and describe remedial measures and design approaches used to solve these problems. The intent is not to establish new design practices, but to concisely document improved design procedures that have been developed from field experiences. Readers are encouraged to use the *Journal's* discussion section to contribute additional information or views on these topics.

Design, operational, and cost considerations for vacuum assisted sludge dewatering bed systems

The vacuum assisted sludge dewatering bed (VASDB) process was developed in the mid-1970s as an alternative to more conventional technologies used at small- to medium-sized wastewater treatment facilities. This innovative technology, three systems of which are currently available, incorporates the application of a vacuum to the underside of a rigid, porous plate grid system on which chemically conditioned sludge has been placed. The vacuum pulls free water through the media plates while the plate system acts as a septum to retain essentially all of the sludge solids. An initial gravity drainage time interval used to remove a portion of the free water through the media plates begins as soon as conditioned sludge is introduced and normally continues for 1–3 hours. After this free drainage period, the vacuum pump activates to mechanically assist removal of additional free water. Upon completion of the vacuum-assisted free water removal cycle and an optional air drying time interval, the partially dewatered sludge is removed, usually with a front-end loader. Next, the plate system is cleaned by rinsing residual sludge solids from the upper surface of the media plates with high pressure water. After this surface cleaning, the system is ready for another application of chemically conditioned sludge. Figures 1 and 2 show plan and section views of an uncovered, one-bed system. In actual practice, most systems have more than one bed and climatic conditions may require enclosure of the entire VASDB system if year-round operation is to be practiced.

This article summarizes findings of post-construction evaluations of 12 operational VASDB systems located at municipal wastewater treatment facilities throughout the U. S. These systems dewatered aerobically and anaerobically digested sludges, undigested secondary sludge from extended aeration and oxidation ditch plants, a mixture of undigested secondary sludge and phosphate precipitation (alum) sludge, Imhoff tank sludge and a lime-conditioned mixture of undigested primary and secondary sludges. An approximately equal number of the three available VASDB systems were also evaluated. Data and information contained in this article include: existing facility design, operational and cost data; and suggested improvements to current design and operational practices.

DESIGN AND OPERATIONAL CONSIDERATIONS

Sludge application. There are two approaches to apply conditioned sludge to vacuum beds. In one, the filtrate drain valve between the bed plennum and the filtrate receiver is closed before sludge application and then the bed is backflooded so that approximately 1.27 cm (0.5 in.) of free standing water accumulates above the surface of the media plates. This backflooding minimizes media plate surface blinding with scum and assists in spreading the conditioned sludge solids uniformly over the entire

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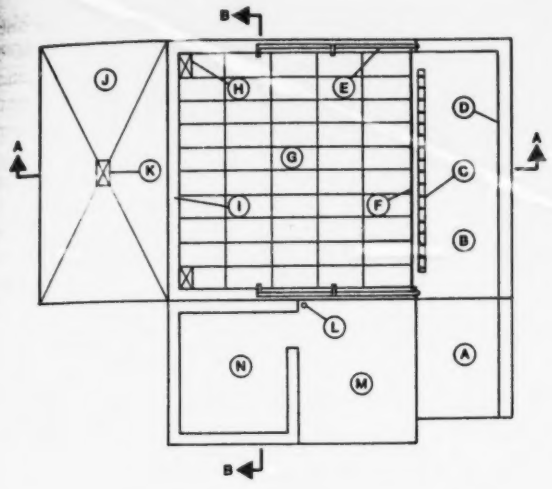


(A) ENTRANCE RAMP
(B) OFF-BED LEVEL AREA
(C) AREA DRAIN
(D) CURBING
(E) SLUDGE DISTRIBUTION PIPING
(F) BED CLOSURE SYSTEM
(G) MEDIA PLATES
(H) CORNER DRAIN
(I) BED CONTAINMENT WALL
(J) TRUCK LOADING AREA
(K) AREA DRAIN
(L) WASH WATER SUPPLY
(M) FEED SLUDGE INVENTORY TANK (BELOW GRADE)
(N) CONTROL BUILDING WITH
-SLUDGE FEED PUMPS
-POLYMER SYSTEM
-VACUUM PUMPS
-CONTROL PANEL
-FILTRATE RECEIVER/PUMPS (BELOW GRADE)

Figure 1—Plan view of a VASDB system.

bed surface area. Once sludge accumulates to a depth of approximately 15.24 cm (6 in.), the filtrate drain valve is opened to initiate gravity drainage. The other approach is to open the filtrate drain valve before sludge application and therefore gravity drainage starts immediately.

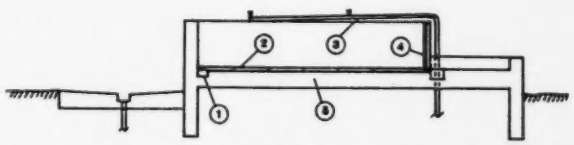
Process cycle. A total cycle of 24 hours, that encompassed application of polymer-conditioned sludge through media plate surface cleaning with high pressure water, normally yielded a liftable dewatered cake. Liftable implies that most of the sludge cake can be removed from the media plates with a front-end loader. Properly conditioned aerobically digested secondary sludges formed a liftable cake of 11–13% total solids (TS) concentration in a 24-hour cycle. Properly conditioned anaerobically digested and lime-conditioned sludges were liftable in less time. If a drier than liftable cake is desired or required, cycle time must be increased or a separate drying area should be used.

Loading rate. Design TS loading rate should be between 8.54–10.98 kg/m^2/application (1.75–2.25 lb/ft^2/application) for aerobically digested sludges. System loading for undigested waste activated sludge should be at a lower rate while that for anaerobically digested and lime-conditioned sludges could be at a higher rate. Analysis of data from 13 operational facilities, summarized in Table 1, shows the distribution in observed sludge solids loading rates.

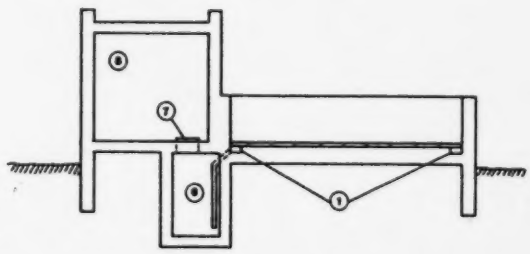
The low observed value of 3.22 kg/m^2/cycle (0.66 lb/ft^2/cycle) was for a system dewatering unthickened oxidation ditch sludge that had a TSS concentration near 8000 mg/L. The high value of 37.82 kg/m^2/cycle (7.75 lb/ft^2/cycle) was associated with a lime-conditioned mixture of primary and waste activated sludges. Median-average values typically correspond to aerobically digested sludges.

Loading and sludge depth. System manufacturers have suggested that 0.30–0.61 m (1–2 ft) of chemically conditioned sludge should be applied to a vacuum bed. Corresponding loading rates for different applied sludge concentrations at these two depths are presented in Table 2. Operators applying less than 0.61 m (2 ft) of less than 1.5% TS aerobically digested sludge are using their VASDBs at less than full capacity. Previously presented operational data indicated a proven solids loading rate of 9.76 kg/m^2/application (2.0 lb/ft^2/application) for dewatering aerobically digested sludge in a 24-hour cycle.

Even though most beds are constructed with 0.61- to 0.76-m (24–30 in.) containment walls, sludge depths greater than the wall height can be applied to achieve a proven system solids loading rate. One facility consistently achieved loadings of approximately 9.52 kg/m^2/cycle (1.95 lb/ft^2/cycle) by applying up to 1.27 m (50 in.) of 7500 mg/L TSS extended aeration treatment plant sludge during single bed cycles. To accomplish this, the system vacuum pump was activated after approximately 0.15 m (6 in.) of conditioned sludge had accumulated on the media plates. Consequently, the vacuum cycle also encompassed the normal gravity drainage cycle and a total cycle of 24 hours produced a liftable cake. Another facility applied 1.5% TS aerobically digested sludge from an extended aeration treatment plant to depths of 0.84 m (33 in.). During each fill cycle, approximately 0.28 m (11 in.) of clear supernatant above the polymer coagulated and thickened sludge solids on the media plates was decanted through cracks between stop logs used for the bed closure system. Remaining on the bed was 0.56 m (22 in.) of sludge solids which had a loading equivalent to 12.54 kg/m^2/cycle (2.57 lb/ft^2/cycle). Within a full cycle of 24 hours, a liftable cake was produced. A third facility consistently realized loadings of 36.60 kg/m^2·d



SECTION A-A



SECTION B-B

(1) FILTRATE COLLECTION CHANNEL
(2) MEDIA PLATES
(3) SLUDGE DISTRIBUTION PIPING
(4) BED CLOSURE SYSTEM
(5) CONCRETE SUPPORT SLAB
(6) FILTRATE RECEIVER/VACUUM VAULT
(7) FILTRATE RECEIVER HATCH
(8) CONTROL BUILDING

Figure 2—Section views of a VASDB system.

Table 1—Distribution of observed sludge solids loading rates.

Calculated value	Solids loading rate	
	kg/m²/cycle	lb/ft²/cycle
Low	3.22	0.66
Median	9.17	1.88
Average	10.64	2.18
High	37.82	7.75

(7.50 lb/ft²/day) while dewatering polymer-conditioned anaerobically digested sludge. This was accomplished by multiple sludge applications during a single cycle. Initially, the bed would be filled to the height of the containment walls and allowed to gravity drain. When drainage stopped, the bed would be refilled with conditioned sludge and the gravity drainage cycle repeated. This fill/gravity drainage was repeated a total of three to four times. Final dewatering was accomplished by activating the system vacuum pump. Containment walls should be approximately 0.91 m (36 in.) for consistent operational practices independent of influent sludge solids concentration.

Through various operational practices, a VASDB system can accept and dewater sludge beyond its nominally rated design capacity. This provides flexibility to the system to handle unanticipated demands brought about by variable treatment plant influent characteristics or seasonal operating strategies.

Polymer pump controls. Polymer usage is primarily a function of the type, concentration, and stabilization of the sludge being dewatered. Usage is also related to the molecular weight, charge density, and percent active ingredients of the polymer selected. Operators should evaluate a number of different polymers to establish the one most cost effective for sludge conditioning.

Laboratory testing can establish optimum polymer dose. However, most operators approximated dose by observing floc formation as the sludge was discharged onto the bed surface and adjusting the polymer pump setting to achieve desired floc characteristics. Variations in influent sludge characteristics during a fill cycle at a number of facilities required periodic adjustment of the polymer feed rate. This was difficult because pump controls were often isolated from the bed and thus polymer feed rate adjustments could not be made rapidly in correspondence with changing sludge characteristics. Therefore, designers should locate polymer pump controls adjacent to each bed.

Cycle frequency and number of beds. The number of VASDBs per facility was between one and four. However, systems with as many as 16 beds have been constructed. Operators of heavily used one-bed facilities felt operational flexibility was limited. If optimum polymer dose was missed, additional dewatering time would be required, thereby upsetting their sludge dewatering schedule. Operators of heavily used two-bed systems felt less constrained, while those with three or four beds felt most comfortable. In future designs, consideration should be given to dewatering frequency: if 5 day/week sludge dewatering is practiced, then a minimum of two beds should be designed.

Field generated data have indicated that an individual bed cannot be operated continuously. Normal end-of-cycle rinsing of the media plates with high pressure water is inadequate to maintain desired plate permeability. Daily use of a bed will eventually cause blinding of the media plates with sludge fines, biological growth, or both. For VASDB systems that are heavily used, beds should be sized for conditioned sludge application approximately 5 days/week. Such intermittent application greatly increases the time interval between required chemical cleaning of the media plates.

Bed size. Standard bed sizes observed during the site visits were predominately 6.10 × 6.10 m (20 × 20 ft) and 6.10 × 12.19 m (20 × 40 ft); however, other sizes have been constructed. There is a trailer mounted system with bed dimensions of 1.83 × 3.66 m (6 × 12 ft) which is hauled by truck to small treatment plants operated by the trailer owner and used for dewatering waste sludge at each facility. Inground systems with bed areas as small as 11.15–14.86 m² (120–160 ft²) are considered feasible for smaller wastewater treatment plants. Bed geometry is left to the discretion of the designer, but media plates are either 0.61 × 0.61 m (2 × 2 ft) or 0.61 × 1.22 m (2 × 4 ft) and their cutting to other dimensions is not recommended.

Bed elevation. Eleven of the 12 systems visited were constructed with media plate elevation set at or below grade. The twelfth was set above grade. Below grade construction forms a natural containment when the bed closure system fails or is not used. However, this elevation requires that the front-end loader be driven to the off-site disposal vehicle loading area to transfer dewatered sludge cake. With at or above grade construction, the natural containment aspect is lost, but direct transfer of cake from the bed to the off-site disposal vehicle is possible. The off-site disposal vehicle can be parked adjacent to the vacuum bed concrete containment wall and the contents dumped from the front-end loader bucket directly into the disposal vehicle. This operation was observed at the facility built above grade. Direct off-loading can save operator and front-end loader running time and can also minimize media plate damage as will be described later in this report. The choice to build at, below, or above grade is left to the design engineer following a thorough analysis of construction, operational, and maintenance costs for different bed elevations.

Entrance ramp. With bed construction above or below grade, an entrance ramp is required. Observed ramps were constructed of dirt, asphalt, and concrete with slopes between 1:3 and 1:7.5. Consideration should be given to use of a curbed, cross-ribbed concrete or asphalt ramp with a maximum slope of 1:4. Such construction material minimizes media plate damage caused by the transfer of dirt or gravel adhering to front-end loader tires onto the bed. A horizontal section approximately 0.91–1.22 m

Table 2—Impact of applied sludge concentrations and depths on solids loading rate.

Applied sludge concentration, %	Solids loading, kg/m² (lb/ft²), at applied depth of			
	0.30 m	0.61 m	12 in.	24 in.
0.5	1.51	3.03	0.31	0.62
1.0	3.03	6.10	0.62	1.25
1.5	4.59	9.13	0.94	1.87
2.0	6.10	12.20	1.25	2.50
2.5	7.61	15.23	1.56	3.12
5.0	15.23	30.45	3.12	6.24

Table 3—Pump operating times and electrical power consumption.

Calculated value	Pump operating time hr/cycle		Power consumption	
	Vacuum	Filtrate	kWh/10³ kg	kWh/ton
Low	0.0	0.4	1	1
Median	20.0	1.3	24	22
Average	14.5	1.3	34	31
High	22.0	2.8	130	118

(3–4 ft) should be constructed adjacent to the bed entrance so that the front-end loader can be horizontally oriented before moving onto the media plates.

Paved loading areas. Most off-site disposal vehicle loading areas observed were gravel. For bed systems built below grade, consideration should be given to paving this area to minimize the transfer of dirt and gravel onto the media plates. For systems built at or above grade where sludge cake off-loading from the bed directly into the off-site disposal vehicle can be implemented, paving of this area may not be warranted.

Sludge distribution headers. A sludge cake of uniform thickness over the entire vacuum bed surface area is necessary to yield optimum dewatering. If the formed cake is thinner in certain areas than in others, it may crack and system vacuum may be lost prematurely. Such vacuum loss inhibits additional free water removal from areas with thicker sludge mats. To minimize potential vacuum loss by non-uniform cake thickness, sludge distribution headers should be installed on two opposing containment walls of a bed. Each header should have adjustable orifices located at 3.05–4.57 m (10–15 ft) intervals. In addition, distribution header width should be less than that of the supporting containment wall. Movement of a front-end loader along all containment walls during sludge cake removal will not be impaired with this header width.

Bed closure system. All sites visited were designed with bed closure systems to contain the sludge on the media plates. Closure system materials included aluminum and fiberglass slide gates, as well as wooden stop logs. Closure system lengths were between 2.44 m (8 ft) and the full width of the bed; height was normally the same as the adjacent containment walls. Certain operators ensured a watertight seal between the closure system and the containment walls. Others arranged their closure system components to allow leakage of clear supernatant from above the flocculated sludge solids on the media plates. Decanting clear supernatant by the latter arrangement of closure system components or by using mechanical decanting equipment, in lieu of drawing all free water through the sludge mat and media plates, is a valuable operational practice. This practice has yielded higher system solids loading rates, yet has not affected a 24-hour cycle time. As an example, use of the supernatant decanting principle at one facility allowed for the completion of three cycles on one bed during a 16-hour work day.

Table 4—Operator time requirements.

Calculated value	Operator time	
	hour/10³ kg	hour/ton
Low	1.1	1.0
Median	3.9	3.5
Average	6.1	5.5
High	20.8	18.9

Table 5—Capital cost variability of existing systems.

Calculated value	Capital cost, dollar/m²		Capital cost, dollar/ft²	
	Uncovered	Enclosed	Uncovered	Enclosed
Low	484	753	45	70
Median	1485	1615	138	150
Average	1324	1679	123	156
High	1991	2293	185	213

To minimize media plate damage by front-end loader maneuvering on a bed, length of the closure system should be equivalent to bed width. This width will also expedite sludge cake removal with the front-end loader. Closure system weight should be such that it can be manually moved by one person. These desired characteristics suggest that wooden stop logs with maximum lengths of 3.05 m (10 ft) should be considered. A removable center post channel may be necessary to allow stop logs to span bed widths in excess of 3.05 m (10 ft).

Drains. After sludge cake removal, the media plates are washed to remove surficial particulate matter and associated polymer. One or two capped floor drains are normally installed in the corner(s) of each bed. A suggested improvement to current design practice involves recessing the capped drains under removable 0.09 m² (1.0 ft²) cover plates. Two edges of the 5–9 cm (2–3.5 in.) thick cover plate should be flush with the containment walls and the top should be flush with the surface of the bed media plates. Removal of the cover plate and drain cap will allow for more complete and faster removal of the surface wash water from the bed surface.

A drain should also be located at the toe of the bed entrance ramp. Such a drain can be used as a supplement to the bed corner drains. More effective is the use of this drain to collect clear supernatant from above the polymer-flocculated and settled sludge solids on the vacuum bed.

Plate leveling and bed settlement. Depending on system manufacturer, media plates are placed either on a flat or slightly sloped concrete slab or on a compacted and leveled gravel layer above a concrete slab. Once the plates are arrayed on the bed and individually leveled, they are bonded together with epoxy to form an integral media surface. Slightly different individual media plate elevations were noted at several facilities. Potential causes included either inadequate shimming between the concrete slab and the media plates or uneven compaction of the gravel layer under the plates. These slight elevation differences did not hinder dewatering. However, high edges on individual media plates were worn excessively from front-end loader bucket contact during sludge cake removal operations. Settlement at several facilities resulted in the corner drains being higher than the vacuum bed surface, making wash water removal difficult. Such situations can be avoided by improved design.

Expansion joints. Media plates have a coefficient of thermal

Table 6—Impact of solids loading rate on size and capital cost of 331.1 × 10^3 kg/a (365 ton/year) facilities.

Loading rate, kg/m²/cycle (lb/ft²/cycle)	Required area, m² (ft²)	System capital cost, dollars		
		Uncovered	Roofed	Enclosed
9.76 (2.0)	130.06 (1 400)	172 200	191 800	218 400
19.52 (4.0)	65.03 (700)	86 100	95 900	109 200
29.28 (6.0)	43.38 (467)	57 441	63 979	72 852
39.04 (8.0)	32.52 (350)	43 050	47 950	54 600

expansion similar to that of concrete. As a consequence, expansion joints are an important component of VASDB systems, especially for beds which are not contained in a building. At a minimum, the expansion joint should encompass the entire perimeter of the bed, placed between the containment walls and the edges of the abutting media plates. The joint itself should contain a diaphragm to ensure a tight seal under all anticipated temperature conditions to prevent system vacuum loss. Manufacturers provide diaphragms applicable to their particular systems.

Media plate cleaning. Scrupulous cleaning of media plates with wash water after each bed use is an important preventive maintenance activity. If not done thoroughly, progressive plate blinding will occur, necessitating time-consuming and expensive chemical cleaning procedures. Operator experience has shown that normal water line pressure, 3.51–4.22 kg/cm² (50–60 psig), provides insufficient cleaning force. Increasing the pressure to 5.62–8.43 kg/cm² (80–120 psig) greatly increases plate surface cleaning and substantially reduces cleaning time. Pressures above 10.54 kg/cm² (150 psig) may cause plate deterioration and, thus, should be avoided.

Even with proper operational and preventive maintenance practices, media plates will show signs of reduced permeability with time. Factors mentioned by system operators as contributing to progressive blinding have included fine grit, oils, greases and other scum forming material in the sludges being dewatered, incorrect polymer dosage, especially overdosing, and biological growth inside the plates caused by continuous, 7 day/week bed use. System manufacturers have formulated various chemical cleaning solutions which are used approximately every 6 months on systems receiving average use. The cleaning procedure involves flooding the bed with water and chemical cleaning solution, allowing the mixture to react for 24 hours and then rinsing the bed with wash water. Aqueous solutions of alkaline detergents, hypochlorite, enzymes, and muriatic acid have been used for media plate cleaning. Long-term effectiveness of these solutions is not known.

Vacuum and filtrate pumps. Filtrate is collected in a receiver following its transport through the media plates under atmospheric or vacuum operating conditions, and subsequently pumped to the wastewater treatment plant. Common to several facilities was frequent and abnormally short filtrate transfer pump operating time, a condition that can lead to pump motor failure. Excessive filtrate pump capacity or inadequate filtrate receiver volumetric capacity could have been the cause. Design engineers should size component capacities to ensure a filtrate pump running time of 60–120 seconds. Another problem was the discharge of vacuum pump carryover onto the control room floor. Floor drains should be installed to collect this carryover. Operators reported their vacuum and filtrate pumps to be very reliable.

Power consumption. Electrical power is consumed primarily by vacuum and filtrate pump operation. Summarized in Table 3 are the operating times and power consumption of these pumps at 11 facilities. One facility did not use its vacuum pump at all; a liftable cake was produced in 24 hours by gravity drainage alone. The remaining 10 facilities operated their vacuum pumps between 4.5 and 22.0 hours/cycle. Long vacuum pump operating time and the concomittant consumption of a vast majority of the system total electrical power is unnecessary since pump operation beyond sludge cake cracking is unnecessary. Normally, vacuum pump operation should not exceed 6 hours/cycle.

Operator time requirements. Daily time requirements for VASDB system operation are allied with polymer solution preparation, polymer dose optimization, dewatered sludge cake removal and media plate washing. Operator time requirements noted from 13 full-scale systems are in Table 4. A system that operated at 37.8 kg TS/m²/cycle (7.75 lb TS/ft²/cycle) and that used a front-end loader for sludge cake removal required the least amount of time. A system that operated at 3.22 kg TS/m²/cycle (0.66 lb TS/ft²/cycle) and that used manual labor to shovel sludge cake from the beds used the most time.

Table 7—Equivalent capital cost, dollars/10^3 kg (dollars/ton), of a 331.1 × 10^3 kg/a (365 ton/year) facility.

Loading rate, kg/m²/cycle (lb/ft²/cycle)	Capital cost, dollars/10^3 kg (dollars/ton)		
	Uncovered	Roofed	Enclosed
9.76 (2.0)	54.46 (49.40)	60.66 (55.02)	69.07 (62.65)
19.52 (4.0)	27.23 (24.70)	30.33 (27.51)	34.54 (31.33)
29.28 (6.0)	18.16 (16.47)	20.22 (18.34)	23.02 (20.88)
39.04 (8.0)	13.62 (12.35)	15.17 (13.76)	17.27 (15.66)

Table 8—Variability in polymer usage costs.

Calculated value	Polymer cost	
	dollar/10^3 kg	dollar/ton
Low	8.60	7.80
Median	28.11	25.50
Average	34.89	31.65
High	98.56	89.40

Table 9—Estimated first year O&M costs.

Item	Estimated first year O&M costs for system cycle loadings of			
	9.76 kg/m² (2.0 lb/ft²)	19.52 kg/m² (4.0 lb/ft²)	29.28 kg/m² (6.0 lb/ft²)	39.04 kg/m² (8.0 lb/ft²)
Labor	12 775	7 026	5 153	4 251
Polymer	9 490	9 490	9 490	9 490
Electricity	365	365	365	365
Front-end loader	365	201	147	121
Plate replacement	1 134	567	378	284
Plate cleaning	280	140	93	70
Total	$24 409	$17 789	$15 626	$14 581

VASDB SYSTEM COST ANALYSIS

VASDB systems can be uncovered, covered with a roof, or totally enclosed in a structure. Uncovered systems are recommended for geographic areas with temperate climates and little precipitation and cost $1324/m² ($123/ft²). Roofed systems, recommended for geographic areas with temperate climates and measurable precipitation, cost $1475/m² ($137/ft²) while totally enclosed systems, recommended for freezing temperature zones, cost $1679/m² ($156/ft²). The above capital costs are averages of the 12 facilities visited as well as from 17 other operational facilities. For more reliable interpretation, system costs were adjusted to the third quarter of 1984 by using the Small Facility Construction Cost Index of the U. S. Environmental Protection Agency (EPA). Adjusted low, median, average, and high capital cost values for uncovered and totally enclosed systems are summarized in Table 5.

System manufacturers supply contractors with media plates, vacuum and filtrate pumps, polymer makeup/feed equipment and a system control panel. For these items and the installation of the media plates, the manufacturers normally receive $377–753/m² ($35–70/ft²) of bed surface area. The remainder of the system cost is associated with concrete work, piping and valving, electrical wiring, a control building for uncovered or roofed systems or a total bed enclosure for covered systems, a front-end loader for dewatered cake removal, an off-site sludge disposal vehicle and, in certain cases, pumps and piping for transferring sludge and filtrate between the wastewater treatment plant and the VASDB system.

Required bed size is primarily a function of solids loading rate. Example systems capable of dewatering 331.1 × 10^3 year (365 tons/year) of dry sludge solids, based on bed use 5 days/week, have the surface areas and capital costs shown in Table 6. Based on a 20-year system life and the acquisition of a 20-year, 8.375% loan, the equivalent capital costs of these systems, in terms of dollars/10^3 kg (dollars/ton) of sludge solids dewatered, would be as in Table 7.

Information on polymer cost to dewater sludge at 11 full-scale operational facilities is summarized in Table 8. The low reported value of $8.60/$10^3$ kg ($7.80/ton) was associated with dewatering lagoon-thickened (3.5–4.0% solids) oxidation ditch sludge. The high reported value of $98.56/$10^3$ kg ($89.40/ton) was associated with dewatering unthickened (0.8% solids) oxidation ditch sludge.

System operation and maintenance (O&M) costs are functions of operator time, polymer and electrical power consumption, front-end loader use, and periodic media plate chemical cleaning and replacement. Assumed rates for the factors used in this cost analysis include labor at $10.00/hour; polymer at $28.67/$10^3$ kg ($26.00/ton) of dry sludge solids dewatered; electricity at $0.05/kWh; media plate replacement at 3%/year at a cost of $290.63/m²; ($27.00/ft²) and chemical cleaning solution at the equivalent of $2.15/m²·a ($0.20 ft²/year). Front-end loader costs include fuel and tune-ups for the vehicle and replacement of the bucket rubber blade every 100 hours of operation. In addition, it has been assumed that an increase in the system loading rate of 9.76 kg/m²/cycle (2.0 lb/ft²/cycle) will increase manpower and front-end loader costs by 10%/m²/cycle (10%/ft²/cycle).

Based on the previous assumptions, estimated first year O&M costs for 4 different solids loading rates are shown in Table 9. Assuming an escalation rate of 5% over the 20-year life of the facility, the average lifetime O&M costs, as a function of system solids loading rate, are as in Table 10. Combining the above

Table 10—Estimated system lifetime O&M costs.

Solids loading rate		Estimated O&M costs	
kg/m²/cycle	lb/ft²/cycle	dollars/10^3 kg	dollars/ton
9.76	2.0	121.89	110.56
19.52	4.0	88.84	80.58
29.28	6.0	78.03	70.78
39.04	8.0	72.82	66.05

Table 11—Estimated system total costs.

Solids loading rate, kg/m²/cycle (lb/ft²/cycle)	Estimated total cost, $10³ kg ($/ton), for VASDB		
	Uncovered systems	Roofed systems	Enclosed systems
9.76 (2.0)	176 (160)	183 (166)	191 (173)
19.52 (4.0)	116 (105)	119 (108)	123 (112)
29.28 (6.0)	96 (87)	98 (89)	101 (92)
39.04 (8.0)	86 (78)	88 (80)	90 (82)

estimated O&M costs with the previously estimated capital costs provides an approximation of VASDB system total costs as presented in Table 11.

A comparison of the estimated total costs in Table 11 with those of a 331.1 × 10^3 kg·a (365 ton/year) sand drying bed system has indicated that VASDB systems are more cost-effective. However, it must be noted that VASDB systems normally yield a cake of 11–13% solids while sand drying beds yield a 30–40% solids cake. Not addressed in this comparison is the fact that different environmental constraints may be placed on the disposal of an 11–13% solids sludge than on 30–40% solids sludge. Sludge disposal costs should be considered by the design engineer on a site-by-site basis, taking into account all local climatic and regulatory factors.

SUMMARY

Post construction evaluations of 12 operational VASDB systems indicated that this innovative technology is an acceptable and cost-effective alternative to more conventional sludge dewatering processes used at small- to medium-sided wastewater treatment facilities. System modifications can be made by designers and operators to improve performance of both existing and new facility installations.

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